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Fog Oil Exposure of U.S. Army Chemical School One Stop Unit Training Students and Cadre with the M1059 and M1057 Mechanized Smoke Generation Systems

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A fog oil smoke exposure assessment investigation was conducted on One Stop Unit Training (OSUT) students from the U.S. Army Chemical School, Fort McClellan, Al, by the U.S. Army Biomedical Research and Development Laboratory, Fort Detrick, MD, while training with the M1059 and M1037 mechanized smoke generation systems. Bulk fog oil samples were also collected and analyzed for mutagenic potential by the Ames assay, and for chromophoric content using the FDA analysis for white oil purity.

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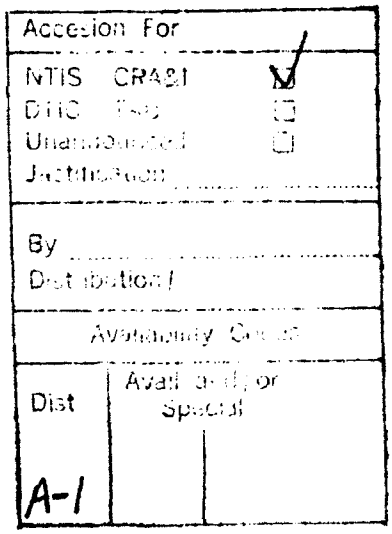

EXECUTIVE SUMMARY

An airborne contaminant routinely encountered in military training is fog oil smoke. U.S. Army doctrine recognizes the importance of deliberately-generated fog oil smoke on the battlefield to mask or obscure objects and emphasizes the need to use fog oil smoke in training environments. However, such use of fog oil exposes soldiers to potentially harmful concentrations of inspirable and respirable particulates.

Fog oil is a naphthenic based cutting oil. In 1985, the International Agency for Research on Cancer (IARC) concluded that conventionally-refined naphthenic oils are carcinogenic (IARC, 1984). In 1986, the military specification for fog oil was modified to exclude all "carcinogenic or potentially carcinogenic constituents" (Dept. of the Army, 1986). Specific limits on chemical constituents and testing procedures to ensure compliance are not addressed in the 1986 military specifications. Oil producers meet the specifications by employing severe hydrotreatment or severe solvent refining processes (Palmer, 1990). Use of these refining methods is presumed to produce a noncarcinogenic fog oil.

Fog oils obtained before the specifications were changed in 1986 are referred to herein as "old" fog oil and those purchased later are referred to as "new" fog oil. The potential hazards associated with "old" fog oil are reduced but not eliminated by the removal of carcinogenic and potentially carcinogenic compounds. In research conducted on the health effects of napthenic mineral oils (IARC, 1984; Bingham et al., 1965; Halder et al., 1984), the skin lesions and cancer of the skin and scrotum were attributed largely to its PAH content. However, it is known from earlier studies that pulmonary effects such as granulomas and pneumonias can still occur with exposure to "new" fog oils (IARC, 1984).

This study was conducted to evaluate the extent of fog oil exposures to soldiers during training with the M1037 and M1059 mechanical smoke generating systems at the U.S. Army Chemical School (USACMLS). Additional data were obtained by performing the Ames Salmonella Assay (Blackburn et al., 1986) and the FDA analysis for white oil purity (Food and Drug Administration, HHS, 1987). In the absence of an exposure standard for fog oil, the threshold limit value (TLV) for mineral oil mist (a substance similar to "new" fog oil) was used as a standard to which personnel exposures to fog oil smoke could be compared (Palmer, 1990).

Personnel exposure levels to mineral oil mist during the One Stop Unit Training (OSUT) Field Training Exercise (FTX) were minimal (0 mg/m^3 - 1.98 mg/m^3). Breathing zone values were well below the TLV for mineral oil mist (5 mg/m^3) set by the American Conference of Governmental Industrial Hygienists (ACGIH) and the Permissible Exposure Limit (PEL) for mineral oil mist (5 mg/m^3) set by the Occupational Safety and Health Administration (OSHA). If the bulk samples were within the specifications outlined by the FDA analysis for white oil purity (Food and Drug Administration, HHS, 1987) masking would not be required. However, when the High UV absorption values found in the FDA analysis and the toxicity evident in the Ames assay are considered, the demand for respiratory protection is increased.

General area sample concentrations were low. A vast majority of the general area values were below the lower level of detection (109 ug/m^3) and indicate minimal contamination of the immediate environment. Environmental exposures to adjacent areas could not be determined .

Bulk oil analyses showed that the samples were free of mutagenic compounds when tested by a modified Ames assay (Blackburn et al., 1986) which produced a mutagenicity index rating of 0. However, high toxicity levels were evident in the modified Ames assay without S-9 and the FDA chromophore analysis displayed large absorption values in the UV region where PAH's are known to absorb. The nature and composition of the compounds causing the toxic effects and high UV absorption values are unknown.

Haas et al.(1987) described a high correlation between the FDA analysis for white oil purity, and the Ames assay (Blackburn et al., 1984) used for predicting the carcinogenicity of petroleum oils. Our

analysis produced UV absorption values in excess of 600 absorbance units in the range of 280 to 289 m*u*. These values, according to Haas et al.(1987), correspond to a high potential for carcinogenicity. This is not reflected in our results from the Ames assay which resulted in a mutagenicity index rating of 0 (non-mutagenetic). The reason for the disparity between the Ames assay and the FDA analysis is unknown but could be due to toxic effects masking mutagenicity.

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1.0 INTRODUCTION

1.1 Research Objectives

An airborne contaminant routinely encountered in military training is fog oil smoke. U.S. Army doctrine recognizes the importance of deliberately-generated fog oil smoke on the battlefield to mask or obscure objects and emphasizes the need to use fog oil smoke in training environments. However, such use of fog oil exposes soldiers to potentially harmful concentrations of inspirable and respirable particulates.

Fog oil is a naphthenic based cutting oil. In 1985, the International Agency for Research on Cancer (IARC) concluded that conventionally-refined naphthenic oils are carcinogenic (IARC, 1984). In 1986, the military specification for fog oil was modified to exclude all "carcinogenic or potentially carcinogenic constituents" (Dept. of the Army, 1986). Specific limits on chemical constituents and testing procedures to ensure compliance are not addressed in the 1986 military specifications. Oil producers meet the specifications by employing severe hydrotreatment or severe solvent refining processes (Palmer, 1990). Use of these refining methods is presumed to produce a noncarcinogenic fog oil.

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This study was conducted to evaluate the extent of fog oil exposures to soldiers during training with the M1037 and M1059 mechanical smoke generating systems at the U.S. Army Chemical School (USACMLS). Additional data were obtained by performing the Ames Salmonella Assay (Blackburn et al., 1986) and the FDA analysis for white oil purity (Food and Drug Administration, HHS, 1987). In the absence of an exposure standard for fog oil, the threshold limit value (TLV) for mineral oil mist (a substance similar to "new" fog oil) was used as a standard to which personnel exposures to fog oil smoke could be compared (Palmer, 1990).

1.2 Scope of the Study

This study was performed to expand the data base generated by previous field surveys concerning the smoke exposure assessment research master plan (Smart, 1989) developed at the USABRDL for assessing military occupational exposures to smoke. Personnel exposure for cadre and students, general area concentrations, and bulk sample composition will be addressed.

1.3 Exposure Scenario

The two training scenarios in which soldiers could be exposed to fog oil smoke are the "operate and maintain" (O&M) and the FTX. In the O&M scenario students learn to operate and maintain the M157 Smoke Generating system (Figure 1). When the M157 is mounted on the Armored Personnel Carrier (APC) or (M113), its proper designation is the M1059 smoke generating system. When mounted on the

Highly Mobile Multi Wheeled Vehicle (HMMWV), it is referred to as the M1037 smoke generating system. In this report, the designation M157 will be used to reference the smoke generator irrespective of its mounting. Subsequent to the O&M training, the students are sent out to the field for the FTX scenario where they operate the generators independently. Several missions where smoke is generated to simulate battlefield conditions are conducted over a number of days.

1.3.1 One Stop Unit Training Course (OSUT)

Smoke training in the OSUT course involves many hours of practical O&M training and a number of FTX's with several missions. For this study, sampling was conducted during one 8-hour FTX mission. This particular mission took place in a bowl shaped valley. Smoke was continuously produced with few intermittent breaks. The mission began at 0900 hrs and ended at 1700 hrs with a 1-hour lunch break from 1130 hrs to 1230 hrs. Twenty-six students and 7 USACMLS cadre were involved in the FTX of these sixteen students and 5 cadre volunteered to participate in the study and were sampled for fog oil exposures. The students were separated into two groups that rotated at set intervals between the M157 Smoke Generating system mounted on the M113 and the M157 mounted on the HMMWV. The students' mission was to cover a large-scale troop movement through a valley. They accomplished this by performing multiple runs across the valley floor while producing copious amounts of fog oil smoke. Throughout the exercise the valley remained enveloped in a constant haze which varied from a light to an opaque cloud.

2.0 MATERIALS AND METHODS

2.1 Fog Oil Smoke Field Sampling

2.1.1 Personnel Breathing Zone Sampling

Various collection media and methods were investigated for the field sampling. Katz (Katz et al., 1980) characterized the chemical and physical composition of fog oil smoke and found that fog oil was vaporized and forced out of the generator, and aerosolized smoke in the form of condensate was immediately formed. The condensate consisted mainly of microdroplets of oil, which could remain airborne for roughly an hour (Katz et al., 1980). Thirty-seven mm grade AAA binderless glass fiber filters (Nuclepore® corporation, Pleasanton, CA) were used as a collection media in accordance with NIOSH method 5026 for Mineral Oil Mist (HEW-NIOSH Pub. No. 84-100, 1984). Since previous research on fog oil smoke dispersion indicated less than 1% vapor phase (Katz et al., 1980), field sampling for the vapor phase was considered inconsequential for this study.

Two days of preparation were required prior to the actual sampling. Forty-six Gilian Dual High Flow Pumps (Gilian® DHFS-113A, Wayne, NJ) were charged for 16 hours and then calibrated with an electronic primary standard (Gilian Gilibrators®, Wayne, NJ) the night before sampling. The flow rates of the Gilian® DHFS-113A pumps with a glass fiber filter in line were adjusted to 0.90 $\pm$ 0.05 LPM in accordance with NIOSH method 5026 for Mineral Oil Mist (HEW-NIOSH Pub. No. 84-100, 1984). Three flow readings were recorded for each pump to arrive at an average calibrated flow rate (Table 1).

Forty of the air sampling pumps equipped with cassette filters and hoses were attached to the modified load-carrying equipment (LCE) (Figure 2). Pumps, tubing, and collection media were wrapped

in pockets and straps to minimize interference with the activities of the soldiers wearing the LCE. The remaining pumps were used as backups.

Pertinent information on test subjects such as tobacco use (an interferent due to IR absorption near 2950 cm^{-1}) and individual status (cadre / student) were recorded prior to sampling (Table 2).

The air sampling pumps were post calibrated immediately after field sampling. All pumps were found to be within $\pm$ 0.02 LPM, < 3 percent of adjusted flow rate (Table 1).

2.1.2 General Area Sampling

Fifteen Alpha[R] I (Dupont, Kennett Square, PA) high flow pumps were used for general area sampling. The Dupont pumps were prepared and calibrated in the same manner as the Gilian[R] high flow pumps. All pumps were activated and in place (Table 3) by 1000 hrs and retrieved at 1700 hrs. The locations of the trail and APC areas within the valley can be found in Figure 3.

2.1.3 Bulk Oil Sampling

Two 50-mL bulk oil samples were collected. Both samples were collected and stored in dark brown 50-mL samples bottle equipped with a teflon cap to prevent photochemical and secondary reactions. The first sample (B-1) was obtained from the main oil storage facility at Ft. McClellan. The sample was drawn from a 50-gallon drum that contained the following information; date of manufacture (2/91); Mil Spec F-12070CAM2; Batch # 23765; Manufacturer (American Lubricating Company). The second 25-mL sample (B-2) was drawn from the Tank and Pump Unit (TPU) that filled the fog oil generators used in the field exercise. Fifty-gallon drums were chosen at random from the main oil storage area to fill the TPU's, therefore the information needed to determine the source of this particular sample could not be obtained. Both samples were identified as "new" fog oil by the date of purchase. They appeared highly refined except for a light yellow tint, both had similar viscosities.

2.2 Soldier Participation

Before field sampling, students and cadre were briefed on the nature, duration and purpose of the research, the methods of sample collection and analysis, and the implications of their voluntary participation. Those who agreed to volunteer filled out and signed a DA Form 5303-R, Volunteer Agreement Affidavit, consenting to participation.

2.3 Breathing Zone and General Area Sample Analyses

The sample cassettes were capped and refrigerated immediately after sampling. A quantitative analysis was performed on all breathing zone and general area samples in accordance with NIOSH method 5026 for Mineral Oil Mist (HEW-NIOSH Pub. No 84-100, 1984). This method entails extraction with trichlorotrifluoroethane followed by infrared analysis. The samples were shipped to a local laboratory for analysis. Four pairs of recovery filters spiked with 200 *ug*, 100 *ug*, 50 *ug* and 10 *ug* of bulk mineral oil and 10 field blanks were analyzed along with the 31 field samples.

2.4 Bulk Sample Analyses

2.4.1 Ames Salmonella Assay

A modification of the Ames assay (Blackburn et al., 1986) was employed to determine the mutagenicity of the "new" fog oil samples. This modification optimizes the Ames Assay (Ames et al., 1975) for testing mineral oils by maximizing the effective dose of potential mutagens delivered to the test system and by maximizing the activation of promutagens to their mutagenic forms. The modification incorporates the following procedures to enhance the sensitivity of the Ames assay to water insoluble complex mixtures such as mineral oils: (a) testing of dimethyl sulfoxide (DMSO) extracts of oils rather than the corresponding neat or organic-solubilized materials; (b) increasing the rat liver homogenate (S-9) concentration to eight times that used in the standard Ames Assay; (c) single-step DMSO extraction of oils dissolved in cyclohexane; (d) the use of hamster rather than rat liver S-9 metabolizing mixture; and (e) the use of 8mM NADP cofactor.

Mutagenicity was determined by the Ames assay (Ames et al., 1975) as modified by Blackburn et al., (1986) with the following exceptions. Hamster liver homogenate was not substituted for the rat liver S-9. In the initial modification to Ames (Blackburn et al., 1984), rat liver S-9 was shown to correlate well with most carcinogenic mouse skin painting assays utilizing complex petroleum hydrocarbon mixtures. Since the hamster liver homogenate was substituted for rat liver S-9 to further increase the sensitivity of the assay to less active mineral oil fractions, the omission was deemed acceptable along with the concomitant loss of sensitivity.

Program Resources, Inc. (PRI) at the Frederick Cancer Research and Development Center, Frederick, MD, performed an initial screening which involved: (a) serial dilutions of each sample to include 100 *u*L undiluted sample and dilutions of 1:1, 1:2, 1:3 and 1:4; (b) two negative controls (bacteria only); (c) two solvent controls (0.1 mL DMSO); and (d) one positive control (2 amino anthracene), in duplicate with and without S-9 (Table 4). Negative and solvent controls were analysed before and after the samples to enhance statistical analyses.

Subsequent testing was considered necessary and followed the general outline given for the initial screening. The additional test differed only in the serial dilutions performed on the samples, (200 *u*L undiluted, 100 *u*L undiluted, 3:1 and 1:1) Table 4.

2.4.2 FDA Analysis for white oil purity

This analysis was performed to determine the purity of the bulk oil samples based on the FDA UV absorbance limits for white mineral oil (Food and Drug Administration, HHS, 1987). The maximum absorbance per centimeter optical pathlength set by the FDA is: 4.0 at 290-289 m*u*, 3.3 at 290-299 m*u*, 2.3 at 300-329 m*u* and 0.8 at 330 to 350 m*u*.

The analysis was performed in accordance with the procedure specified by the Food and Drug Administration (FDA) in 21CFR178.3620(b), (Code of Federal Regulations, 1979). Extractions were performed using hexane and dimethyl sulfoxide. The DMSO portion was collected and designated as the mineral oil extract. The absorbance of the mineral oil extract was determined in a 10-mm cell in the range 260-350m*u* inclusive and compared to a solvent control.

3.0 STATISTICAL METHODS

3.1 Ames Salmonella Assay

In Blackburn's analysis (Blackburn et al., 1984) thirteen petroleum derived oils were ranked according to their relative mutagenic activity. A correlation coefficient of r = 0.97 was obtained when compared to the tumorigenic potency rankings of the same samples previously determined by mouse skin painting bioassays. Samples having a revertant colony count less than two times the background level posses a mutagenicity Index rating of 0 and are considered non-mutagenic. Mean values and standard deviations were determined for each set of plates and can be found in Table 4.

3.2 FDA Analysis for white oil purity

The analysis performed for the detection of chromophores as applied to this report does not lend itself to statistical analysis. Quantification of the chromophoric content was not intended. The aim of the analysis was to obtain a relative comparison between technical white mineral oil and the fog oil bulk samples.

3.3 Breathing Zone and General Area Analyses

All breathing zone and general area samples were evaluated in accordance with the NIOSH confidence level analysis.

$$UCL/LCL = X' +/- 1.645\ (S_r)$$

X' = Standardized 8 hr TWA (TWA/PEL)
S_r = Overall precision for method 5026 (0.065)
UCL = Upper Confidence Level
LCL = Lower Confidence Level
PEL = 5 mg/m^3 (29 CFR 1910.1000, "Mineral Oil Mist")

Upper and lower confidence levels can be found in Table 5.

4.0 RESULTS

4.1 Breathing Zone

Time Weighted Average (TWA) breathing zone values listed in Table 6 were derived from the equation:

$$C = (M - B)/V$$

C = TWA value (mg/m^3).
M = Sample mass (mg), corrected for R.
B = Average blank values (mg).
V = Volume sampled (m^3).
R = Recovery correction factor obtained from a linear regression curve of spike values (mg) vs. mineral oil recovered (mg) (Figure 4).

The TWA values acquired for the breathing zone samples, (Table 6) were far below the TLV ($5mg/m^3$) set by the ACGIH, and the PEL ($5\ mg/m^3$) set by the OSHA. The highest recorded concentration was $1.98\ mg/m^3$.

Variation in exposure between the cadre and the students is not evident, both groups exhibited a wide range of exposures, $0\ mg/m^3$ to $1.98\ mg/m^3$ for the students and $0.30\ mg/m^3$ to $1.32\ mg/m^3$ for the cadre. The mean exposure values for the cadre and the students were $0.89\ mg/m^3$ and $1.07\ mg/m^3$, respectively.

4.2 General Area

General area TWA values listed in Table 6 were calculated in accordance with the equation cited in the previous section. General area exposures were minimal. All but one of the samples, T2404GA (.43 mg/m^3), were below detectable limits (BDL).

4.3 Bulk Samples

4.3.1 Ames Salmonella Assay

The initial screening demonstrated toxic effects throughout the dilution series and borderline enhanced mutagenicity between the 1:1 dilution and the undiluted sample (Table 4).

Mutagenicity is considered significant when a revertant colony count is consistently greater than two times the background. Two times the background is the mean value of the negative and solvent control values times 2. Two samples B-1 (1:1 dilution) and B-2 (undiluted 100 μL) approached significance and warranted additional testing.

The second test was conducted to provide conclusive results pertaining to mutagenicity in the 1:1 and the undiluted sample range by increasing the amount of undiluted sample added to the plates and by narrowing the dose range between the undiluted sample and the 1:1 dilution (Table 4). The results of the second survey show the mineral oil samples to be nonmutagenic.

Toxic effects were evident in the second assay as well as the initial screening. Lawn formation was inhibited in virtually all of the samples plated without S-9. The nature of the toxic agents affecting the tester bacteria is unknown.

4.3.2 FDA Analysis for white oil purity

The UV scans show high concentrations of conjugated species in both samples. Dilutions of 2, 20, 200, and 2000 fold were needed to bring portions of the spectra on scale. Figures 5 (representing sample B-1) and 6 (representing sample B-2) contain four spectra of each of the following dilutions: 2, 20, 200, and 2000. All dilutions were carried out in DMSO. Three peaks were isolated for each sample and their values compared to the UV absorbance limits listed in 21 CFR Ch.1 (4-1-87 Edition), Part 178.3620, for mineral oil mist (Table 7). The wavelengths selected for analysis were: 323 mμ (sample B-1 and B-2); 296 mμ (sample B-1 and B-2); 266 mμ for (sample B-1); and 263 mμ for (sample B-2), which correspond to maximum UV absorption limits for mineral oil mist of 2.3, 3.3, 4.0 and, 4.0 absorbance units, respectively. All of the absorption values listed in Table 9 incorporate the appropriate dilution factor.

5.0 CONCLUSION

Personnel exposure levels to mineral oil mist during the One Stop Unit Training (OSUT) Field Training Exercise (FTX) were minimal (0 mg/m^3 - 1.98 mg/m^3). Breathing zone values were well below the TLV for mineral oil mist (5 mg/m^3) set by the ACGIH and the PEL for mineral oil mist (5 mg/m^3) set by OSHA. If the bulk samples were within the specifications outlined by the FDA analysis for white oil purity (Food and Drug Administration, HHS, 1987) masking would not be required. However, when the high UV absorption values found for the bulk fog oil samples by the FDA analysis and the toxic effects which were observed during the Ames assay are considered, the requirement for respiratory protection becomes necessary.

General area sample concentrations were low. A vast majority of the general area values were below the lower level of detection (109 μg/m^3) and indicate minimal contamination of the immediate environment. Environmental exposures to adjacent areas could not be determined .

Bulk oil analyses showed that the samples were free of mutagenic compounds when tested by a modified Ames assay (Blackburn et al., 1986) which produced a mutagenicity index rating of 0. However, high toxicity levels were evident in the modified Ames assay without S-9 and the FDA chromophore analysis displayed large absorption values in the UV region where PAH's are known to absorb. The nature and composition of the compounds causing the toxic effects and high UV absorption values are unknown.

One anomaly was discovered in the survey and should be mentioned. Haas et al. (1987), showed that the FDA analysis for white oil purity, a simple analytical test, had a high correlation to the Ames assay (Blackburn et al., 1984) for predicting the carcinogenicity of petroleum oils. Our analysis produced UV absorption values in excess of 600 absorbance units in the range of 280 to 289 mμ. These values, according to Haas et al. (1987), correspond to a high potential for carcinogenicity. This is not reflected in our results from the Ames assay which resulted in a mutagenicity index rating of 0 (non-mutagenetic). The reason for the disparity between the Ames assay and the FDA analysis is unknown but could be due to the high toxicity masking mutagenicity.

6.0 RECOMMENDATIONS

Although fog oil mist exposure concentrations were lower than the OSHA PEL and the ACGIH TLV for mineral oil mists, personnel protective equipment (PPE) and/or control measures to reduce exposures to students and cadre during OSUT field training exercises with mechanical smoke generating systems are recommended. This recommendation is due mainly to the high UV absorption values found for the bulk fog oil samples by the FDA analysis for white oil purity and the toxic effects which were observed during the Ames assay. These results indicate composition differences between fog oil and the white mineral oils for which the OSHA and ACGIH standards are intended.

Additional studies involving qualitative and quantitative analysis of "new" fog oil supplies should be conducted. The components causing the toxic effects in the Ames assay and the high UV absorbance in the FDA analysis could be the result of random contamination since only two bulk oil samples were collected. However, a comprehensive survey involving testing of a large cross section of fog oil supplies will provide a competent data base for determining if a screening program to assure "new" fog oil purity should be instituted.

Studies involving cloud dispersion and extended environmental exposures should be considered. General area levels were low but meteorological effects were not considered and could have caused higher exposures in adjacent areas.

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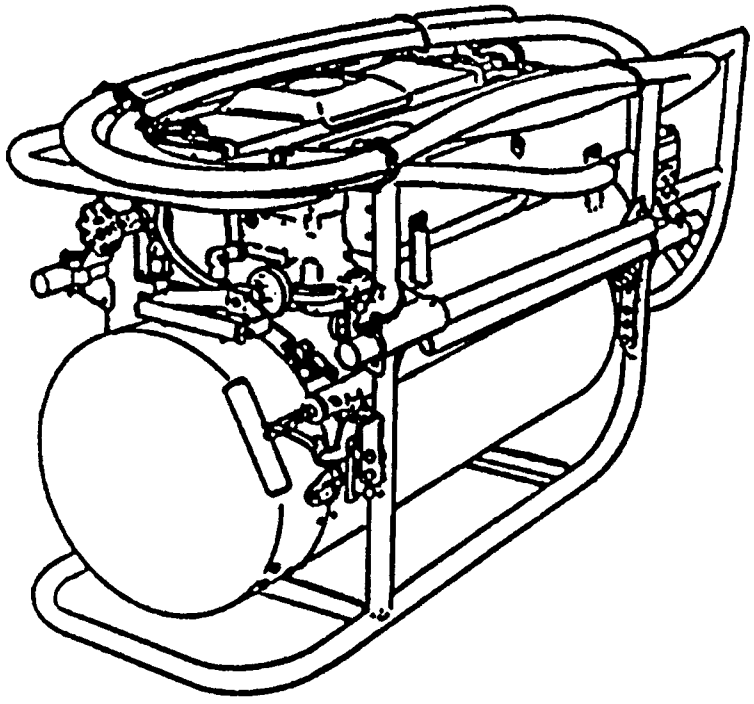
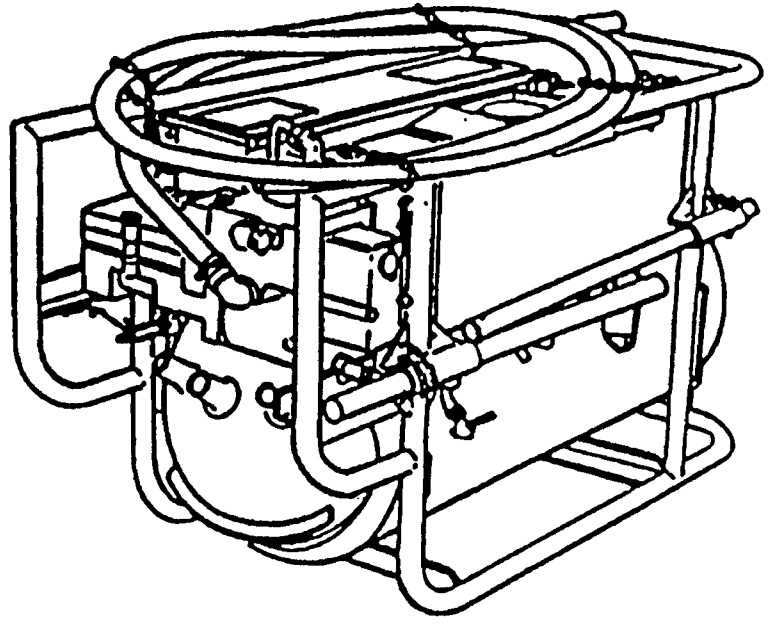
(Figure 1)

M157 Mechanical Smoke Generation System



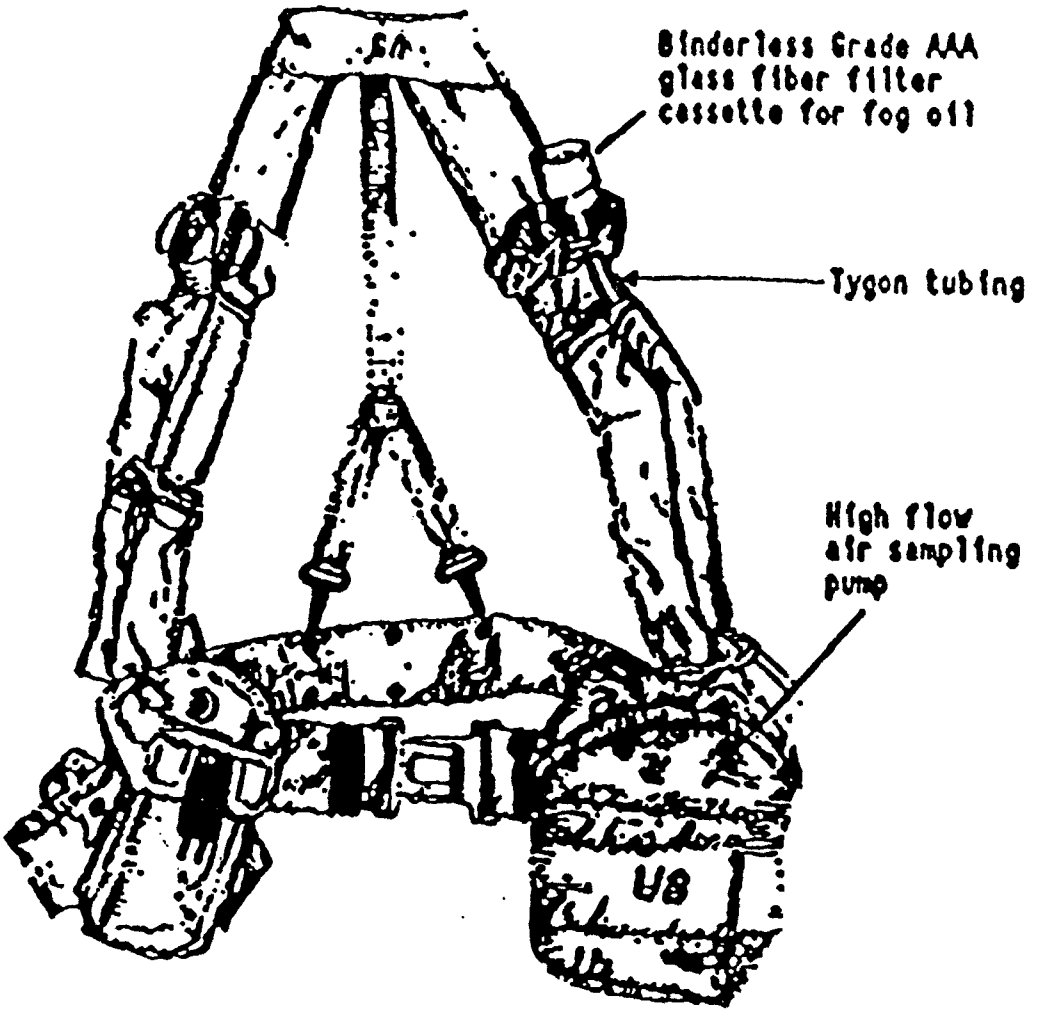
FRONT COVER END



SMOKE DISCHARGE END

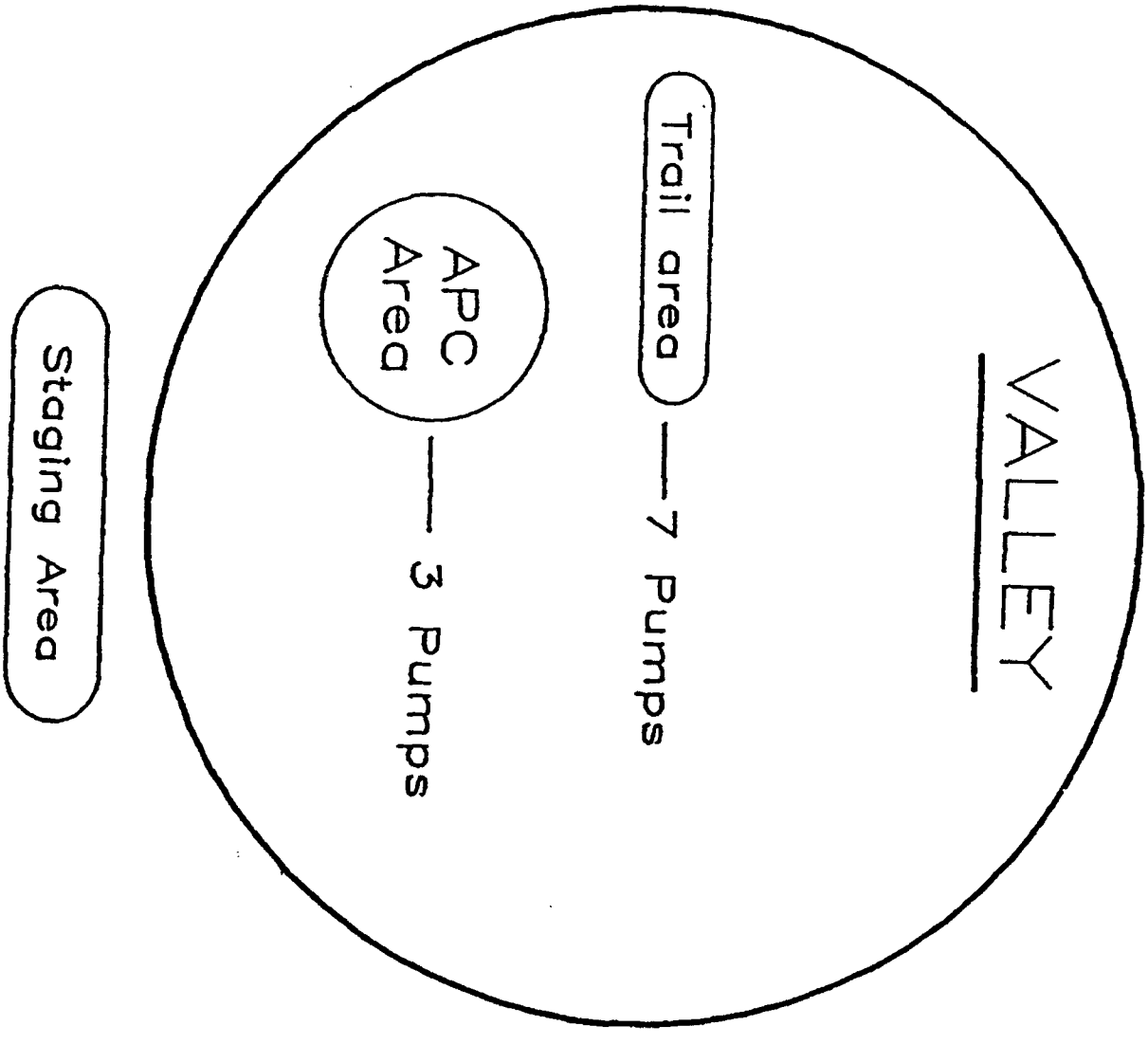
(Figure 2)

Modified Load-Carrying-Equipment with Breathing-Zone Sampling Equipment



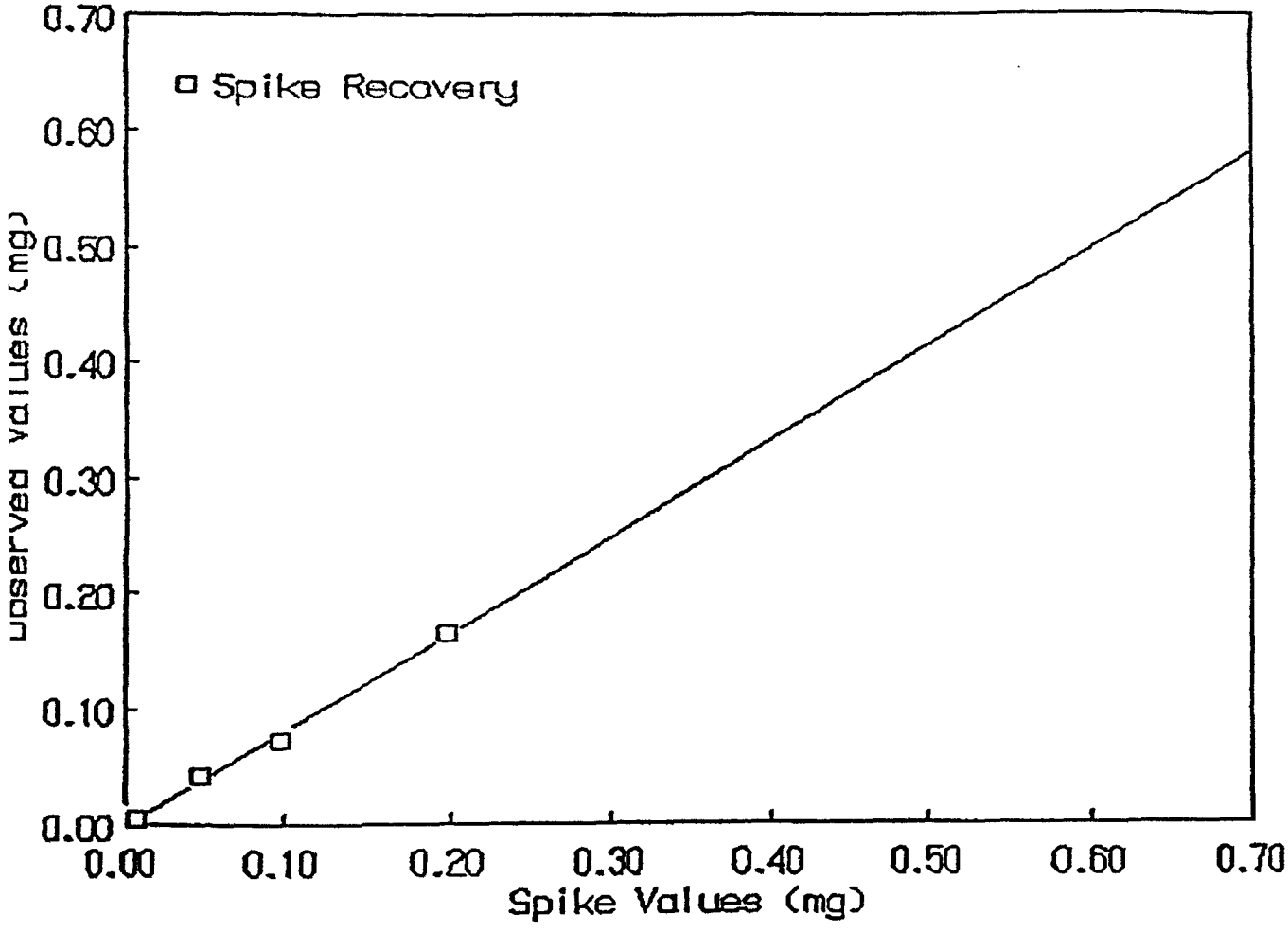
(Figure 3)

FIELD SAMPLING LOCATIONS



(Figure 4)

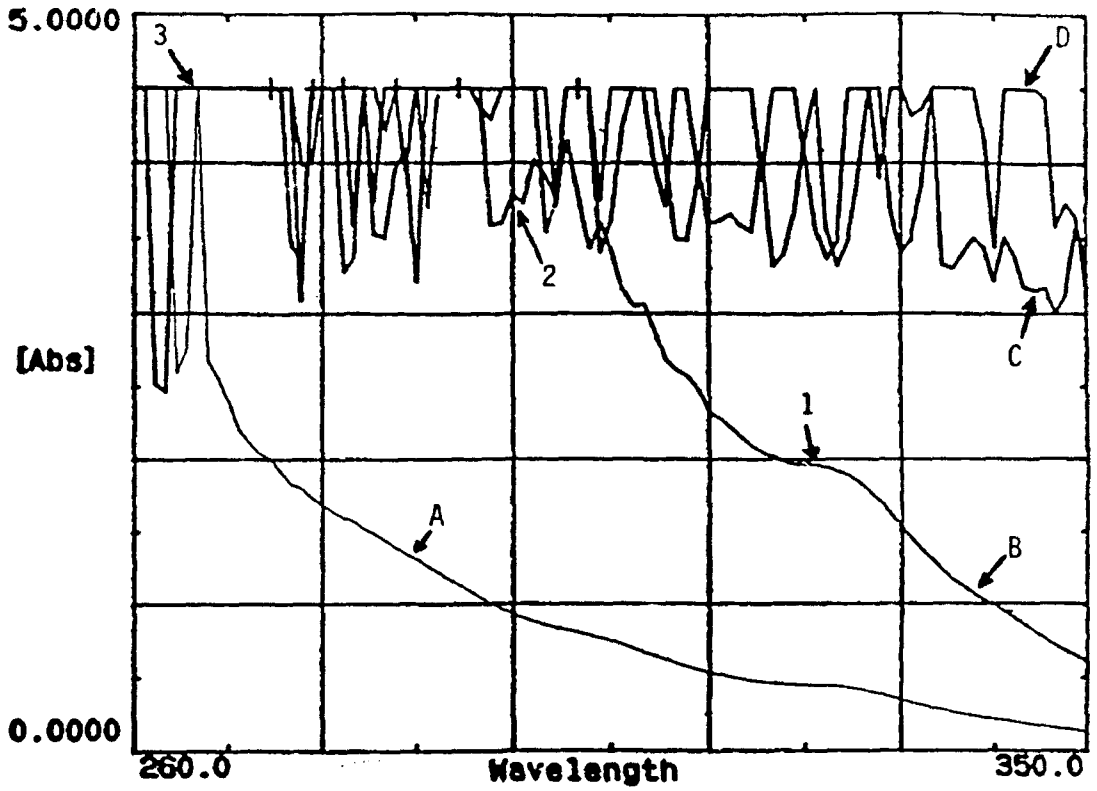
RECOVERY CURVE (R)



	Spike Values (mg)	Observed Values (mg)	% Recovery
SPIKE #1	0.010	0.007	70.0
SPIKE #2	0.050	0.043	86.0
SPIKE #3	0.100	0.075	75.0
SPIKE #4	0.200	0.167	83.5

(Figure 5)

UV SCAN OF SAMPLE B-1



D - Represents a 2 fold dilution of sample B-1

C - Represents a 20 fold dilution of sample B-1

B - Represents a 200 fold dilution of sample B-1

A - Represents a 2000 fold dilution of sample B-1

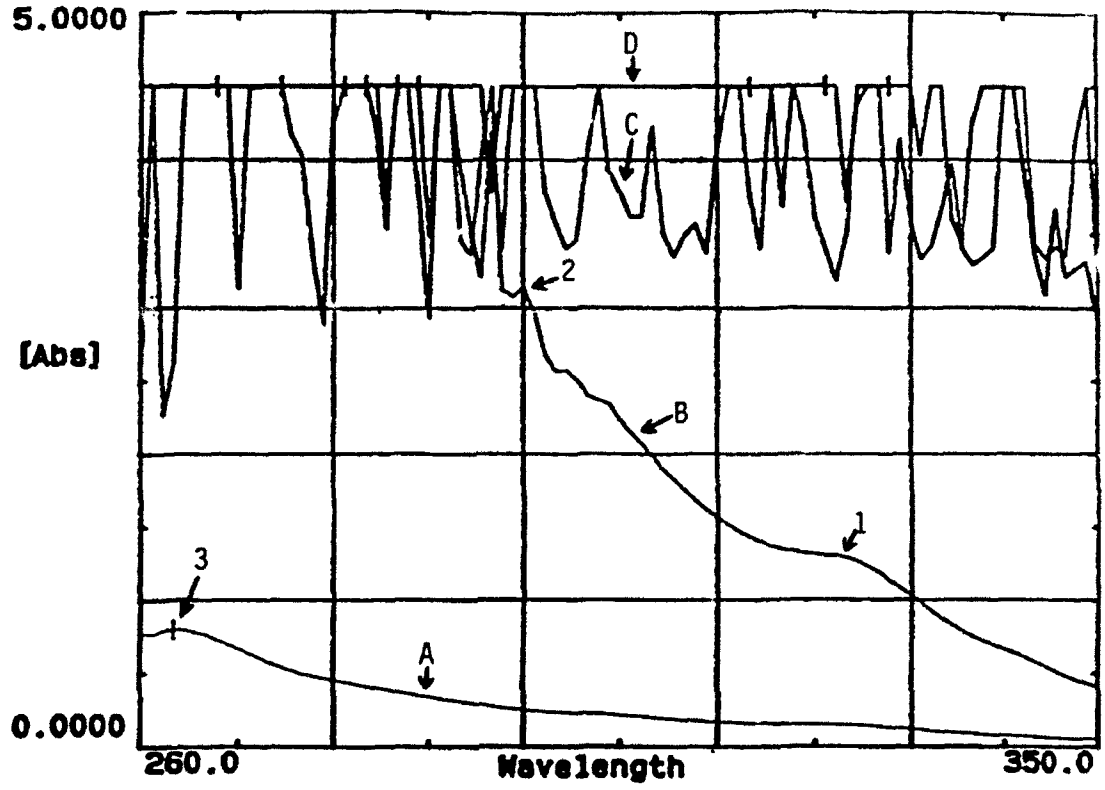
Peak #1 - Wavelength (323 mu), Absorbance (394 units)
FDA maximum absorbance (2.3 units)

Peak #2 - Wavelength (296 mu), Absorbance (760 units)
FDA maximum absorbance (3.3 units)

Peak #3 - Wavelength (266 mu), Absorbance (10,000 units)
FDA maximum absorbance (4.0 units)

(Figure 6)

UV SCAN OF SAMPLE B-2



D - Represents a 2 fold dilution of sample B-2

C - Represents a 20 fold dilution of sample B-2

B - Represents a 200 fold dilution of sample B-2

A - Represents a 2000 fold dilution of sample B-2

Peak #1 - Wavelength (323 mu), Absorbance (260 units)
FDA maximum absorbance (2.3 units)

Peak #2 - Wavelength (296 mu), Absorbance (630 units)
FDA maximum absorbance (3.3 units)

Peak #3 - Wavelength (263 mu), Absorbance (1,640 units)
FDA maximum absorbance (4.0 units)

Table 1
CALIBRATION DATA FOR GENERAL AREA AND BREATHING ZONE SAMPLES

Sample #	Pre Cal (L/Min)	Post Cal (L/Min)	Sample Time (Min)	Total volume (L)
T2397GA	.9044	.9125	433.0	393.4
T2395GA	.9189	.8695	433.0	387.2
T2413GA	.9125	.8803	430.0	385.4
T2410GA	.9161	.8913	428.0	386.8
T2393GA	.9116	.8654	436.3	387.6
T2404GA	.9080	.8553	423.0	372.9
T2396GA	.9009	.8888	424.0	379.4
T2406GA	.9335	.8662	422.0	379.7
T2408GA	.9152	.8611	429.0	381.0
T2407GA	.9000	.8794	428.0	380.8
T1719BZ	.9217	PF	PF	PF
T0933BZ	.9521	.9511	452.5	430.6
T1728BZ	.9009	.9063	460.0	415.7
T0917BZ	.9016	.8940	449.0	403.1
T1710BZ	.9337	.9541	476.8	450.1
T0929BZ	.9062	.8963	471.6	425.0
T1718BZ	.9337	PF	PF	PF
T0919BZ	.9225	.9162	453.0	416.5
T1723BZ@	.9226	.9309	456.4	423.0
T1699BZ	.9185	.9189	461.8	424.3
T0911BZ	.9366	.9089	451.0	416.2
T1726BZ	.9246	1.085	462.0	464.2
T1702BZ	.9116	.9258	457.0	419.9
T0950BZ	.9178	.9116	459.0	419.9
T1731BZ	.9144	PF	PF	PF
T0945BZ	.9016	.9045	447.4	404.0
T0953BZ	.9309	PF	PF	PF
T0922BZ	.9018	.8845	454.3	405.8
T0921BZ	.9076	.9288	455.4	418.2
T1732BZ	.9267	PF	PF	PF
T0948BZ	.9023	.9394	457.47	421.3

PF - Pump Failure
@ - Pinched Tubing Restricted Air Flow

Table 2
BREATHING ZONE SAMPLING DATA
PERSONAL CHARACTERISTICS

Sample #	Student or Cadre	Smoker	Comments
T1719BZ	Student	N	Pump faulted due to a crimp formed in the tubing
T1718BZ	Student	N	Pump faulted due to a crimp formed in the tubing
T1702BZ	Student	N	No problems encountered
T0917BZ	Student	N	No problems encountered
T0933BZ	Student	N	No problems encountered
T1732BZ	Cadre	Y	Pump faulted due to a crimp formed in the tubing
T0911BZ	Cadre	N	No problems encountered
T1699BZ	Student	N	No problems encountered
T0922BZ	Student	Y	No problems encountered
T0929BZ	Student	N	No problems encountered
T1731BZ	Student	N	Pump faulted due to a crimp formed in the tubing
T0945BZ	Cadre	Y	No problems encountered
T1710BZ	Student	N	No problems encountered
T1728BZ	Student	N	No problems encountered
T0921BZ	Student	N	No problems encountered
T0919BZ	Cadre	N	No problems encountered
T0950BZ	Student	N	No problems encountered
T1726BZ	Drill SGT	N	No problems encountered
T0953BZ	Student	N	Pump faulted due to a crimp formed in the tubing
T0948BZ	Student	N	No problems encountered
T1723BZ	Student	Y	Pump faulted due to a crimp formed in the tubing

Table 3
GENERAL AREA SAMPLING DATA
GA PUMP PLACEMENT

Sample #	Site Area	Description of Placement	Comments
T2406GA	APC Area	Placed in a tree roughly 3 ft. above ground	No problems encountered
T2393GA	Trail Area	Placed in a tree roughly 3 ft. above ground	No problems encountered
T2413GA	Trail Area	Placed in a tree roughly 3 ft. above ground	No problems encountered
T2407GA	Trail Area	Placed in a tree roughly 3 ft. above ground	No problems encountered
T2404GA	APC Area	Placed in a tree roughly 3 ft. above ground	No problems encountered
T2395GA	Trail Area	Placed in a tree roughly 3 ft. above ground	No problems encountered
T2397GA	Trail Area	Placed in a tree roughly 3 ft. above ground	No problems encountered
T2410GA	Trail Area	Placed in a tree roughly 3 ft. above ground	No problems encountered
T2396GA	APC Area	Placed in a tree roughly 3 ft. above ground	No problems encountered
T2408GA	Trail Area	Placed in a tree roughly 3 ft. above ground	No problems encountered

Table 4
MEANS AND STANDARD DEVIATIONS FOR THE AMES ANALYSES

INITIAL SCREENING

Test Compound	Mean Values / 1 SD Without S-9	With S-9
B-1 (undiluted 100 *u*L)	19.0 / NA	70.5 / 5.5
B-1 (1:1 dilution)	16.0 / NA	77.5 / 3.5
B-1 (1:2 dilution)	NA / NA	54.5 / 1.5
B-1 (1:4 dilution)	NA / NA	66.5 / 10.5
B-2 (undiluted 100 *u*L)	NA / NA	73.5 / 5.5
B-2 (1:1 dilution)	NA / NA	54.0 / 1.0
B-2 (1:2 dilution)	NA / NA	71.0 / 5.0
B-2 (1:4 dilution)	16.5 / 2.5	67.0 / 7.0
Positive Control	32.0 / 8.0	111.0 / 4.0
2 X Background	37.5 /11.9	79.2 / 9.5

SECONDARY TESTING

Test Compound	Mean Values / 1 SD Without S-9	With S-9
B-1 (undiluted 200 *u*L)	NA / NA	47.5 / 12.5
B-1 (undiluted 100 *u*L)	NA / NA	58.0 / 3.0
B-1 (3:1 dilution)	NA / NA	58.5 / 15.5
B-1 (1:1 dilution)	7.0 / NA	64.0 / 6.0
B-2 (undiluted 200 *u*L)	0.0 / NA	37.5 / 11.5
B-2 (undiluted 100 *u*L)	3.0 / NA	61.0 / 7.0
B-2 (3:1 dilution)	NA / NA	38.5 / 2.5
B-2 (1:1 dilution)	10.0 / NA	61.5 / 0.5
Positive Control	54.0 / 3.0	161.0 / 71.0
2 X Background	37.5 / 14.9	88.2 / 15.8

NA (mean values) - Colony count not available due to the lack of lawn formation
NA (standard deviations) - Mean values could not be obtained or mean value based on one sample only
2 X background - The mean value of the negative and solvent control values times 2

Table 5
UCL'S AND LCL'S FOR BREATHING ZONE AND GENERAL AREA SAMPLES

SAMPLE #	TWA MG/M³	UCL	LCL
T2397GA	0.00	.107	BDL
T2395GA	0.00	.107	BDL
T2413GA	0.00	.107	BDL
T2410GA	0.00	.107	BDL
T2393GA	0.00	.107	BDL
T2404GA	0.43	.193	BDL
T2396GA	0.00	.107	BDL
T2406GA	0.00	.107	BDL
T2408GA	0.00	.107	BDL
T2407GA	0.00	.107	BDL
T1719BZ	PF	NA	NA
T0933BZ	0.93	.293	.079
T1728BZ	1.50	.407	.193
T0917BZ	1.34	.375	.161
T1710BZ	0.24	.155	BDL
T0929BZ	0.21	.149	BDL
T1718BZ	PF	NA	NA
T0919BZ	1.03	.313	.099
T1723BZ	0.00	.107	BDL
T1699BZ	1.86	.479	.265
T0911BZ	1.32	.371	.157
T1726BZ	0.90	.287	.073
T1702BZ	1.67	.441	.227
T0950BZ	1.98	.503	.289
T1731BZ	PF	NA	NA
T0945BZ	0.30	.167	BDL
T0953BZ	PF	NA	NA
T0922BZ	1.16	.339	.125
T0921BZ	0.93	.293	.079
T1732BZ	PF	NA	NA
T0948BZ	1.09	.325	.111

NA - Not Available Due to Pump Failure
BDL - Values Below Lower Detection Limits

Table 6
BREATHING ZONE AND GENERAL AREA SAMPLE RESULTS

Sample #	Initial Results mg/filter	Corrected values (m) mg/filter	Total Volume Sampled m^3	TWA mg/m^3
Blanks (10)	BDL	BDL	NA	NA
T2397GA	BDL	BDL	.3934	0.00
T2395GA	BDL	BDL	.3872	0.00
T2413GA	BDL	BDL	.3854	0.00
T2410GA	BDL	BDL	.3868	0.00
T2393GA	BDL	BDL	.3876	0.00
T2404GA	0.13	0.16	.3729	0.43
T2396GA	BDL	BDL	.3794	0.00
T2406GA	BDL	BDL	.3797	0.00
T2408GA	BDL	BDL	.3810	0.00
T2407GA	BDL	BDL	.3808	0.00
T1719BZ	PF	PF	PF	PF
T0933BZ	0.33	0.40	.4306	0.93
T1728BZ	0.52	0.62	.4157	1.50
T0917BZ	0.45	0.54	.4031	1.34
T1710BZ	0.09	0.11	.4501	0.24
T0929BZ	0.07	0.09	.4250	0.21
T1718BZ	PF	PF	PF	PF
T0919BZ	0.36	0.43	.4165	1.03
T1723BZ	BDL	BDL	.4230	0.00
T1699BZ	0.66	0.79	.4243	1.86
T0911BZ	0.46	0.55	.4162	1.32
T1726BZ	0.35	0.42	.4642	0.90
T1702BZ	0.58	0.70	.4199	1.67
T0950BZ	0.69	0.83	.4199	1.98
T1731BZ	PF	PF	PF	PF
T0945BZ	0.10	0.12	.4040	0.30
T0953BZ	PF	PF	PF	PF
T0922BZ	0.39	0.47	.4058	1.16
T0921BZ	0.32	0.39	.4182	0.93
T1732BZ	PF	PF	PF	PF
T0948BZ	0.38	0.46	.4213	1.09

PF - Pump Failure
NA - Not Applicable
BDL - Below Detection Limits (0.05 mg/filter)

GA - General Area
BZ - Breathing Zone

Table 7
ABSORBANCE VALUES FROM UV ANALYSES

Sample #	Peak #	Wavelength	Absorbance	FDA Maximum Absorbance
B-1	1	323 mμ	394	2.3
B-1	2	296 mμ	760	3.3
B-1	3	266 mμ	10,000	4.0
B-2	1	323 mμ	260	2.3
B-2	2	296 mμ	630	3.3
B-2	3	263 mμ	1,640	4.0

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